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SOME REFRIGERATION TESTS OF A MOTOR TRUCK-TRAILER EQUIPPED WITH ONE TYPE OF DRY ICE SYSTEM OF REFRIGERATION.

(AN INTERIM REPORT)

UNITED STATES DEPARTMENT OF AGRICULTURE
PRODUCTION AND MARKETING ADMINISTRATION
Marketing and Facilities Research Branch

and

AGRICULTURAL RESEARCH ADMINISTRATION
Bureau of Plant Industry, Soils, and Agricultural Engineering
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PREFACE

The tests described in this report were part of a series of studies covering equipment and methods being used to transport perishable commodities to market.

Acknowledgment is made to the following individuals and companies for their assistance and cooperation during the tests:

J. A. Podmore, General Traffic Manager, Minute-Maid Corporation, and Russell A. Barr, General Traffic Manager, Snow Crop Marketers, for furnishing test loads.

The Strick Trailer Company, for supplying the test trailer.

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The study on which this report is based was conducted, in part, under authority of the Agricultural Marketing Act of 1946 (RMA, Title II).

SUMMARY

The tests reported in this publication were conducted to determine the ability of one type of dry ice system of refrigeration to hold frozen foods at or near loading temperatures during the transit period, and to obtain other pertinent information concerning the refrigerating unit, such as ice consumption, reliability, and maintenance problems.

One preliminary performance test and four transit tests were conducted during a 3-month period from August to October 1952. However, owing to adverse conditions encountered during the loading and transit period of one test, it was possible to draw conclusions concerning ice consumption and refrigerating efficiency from only three of the four transit tests.

The preliminary performance test was conducted over a 24-hour period in August 1952. It was found that 18 hours were required to reduce the temperatures inside the trailer from 57° to 0° F. The ice consumption rate for the 24-hour period was approximately 33 pounds per hour. From a total supply of 960 pounds of dry ice, 790 pounds were consumed.

The three transit tests showed average temperature rises between the times of loading and unloading of 6.0°, 3.4°, and 7.2° F. For the three tests combined, the average loading and unloading temperatures were -4.0° and +1.6° F., respectively. Outside temperatures ranged from 52° to 98° F. during the two transcontinental tests, and for the Florida to Texas and Florida to New Jersey tests, the range was 70° to 95° F.

The quantities of dry ice consumed while the test trailers were in transit ranged from 20 to 26 pounds per hour. Except in one instance, dry ice was available when needed throughout the test periods at a cost of 3.1 cents per pound. No mechanical difficulties in the refrigeration system were encountered during the tests.

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INTRODUCTION

The problem of providing adequate and economical refrigeration for long-distance truck shipments has long been a difficult one for persons engaged in the transportation of frozen foods. Through research work and the combined efforts of carriers, shippers, and equipment manufacturers, refrigerated transportation service has improved during the last few years.

A dry ice refrigerating unit similar to the one described in this report was first tested by the Department of Agriculture in May 1951 (H.T. & S. Office Report No. 252). At that time it was recommended that the manufacturer should install a larger dry ice bunker than the one used in the first test because the unit tested appeared to be incapable of holding the extremely low temperatures required for the transportation of frozen foods. The manufacturer, after increasing the capacity of the ice bunker by approximately 50 percent, as suggested, requested the Department to test the new unit.

In order to obtain as much information as possible concerning the efficiency of the dry ice system of refrigeration under different operating and climatic conditions, six road tests were conducted during a 3-month period from August to October 1952. The loads on four of the tests consisted of frozen citrus concentrate with desired transportation temperatures of 0° F.; the other two test loads comprised meat products having maximum temperature requirements of not more than 38° F. The latter tests will be the basis of a separate report and therefore are not included in this publication.

TEST TRAILER

A dry ice bunker was installed in a 32-foot-6-inch tandem semi-trailer with 6 inches of fiberglass insulation in the walls, flooring,

and ceiling. Outside sheathing of the test trailer was aluminum and inside sheathing was plywood. The side walls of the interior of the trailer were stripped vertically with wooden slats, 2 inches wide and 7/8-inch thick, spaced 6 inches apart. Floor racks of 1" by 3" lumber allowed a space of slightly more than 2 inches for the circulation of air underneath the load and five 2" by 1-5/8" wooden strips, spaced 6 inches apart, were nailed vertically to each of the rear doors (fig. 1).

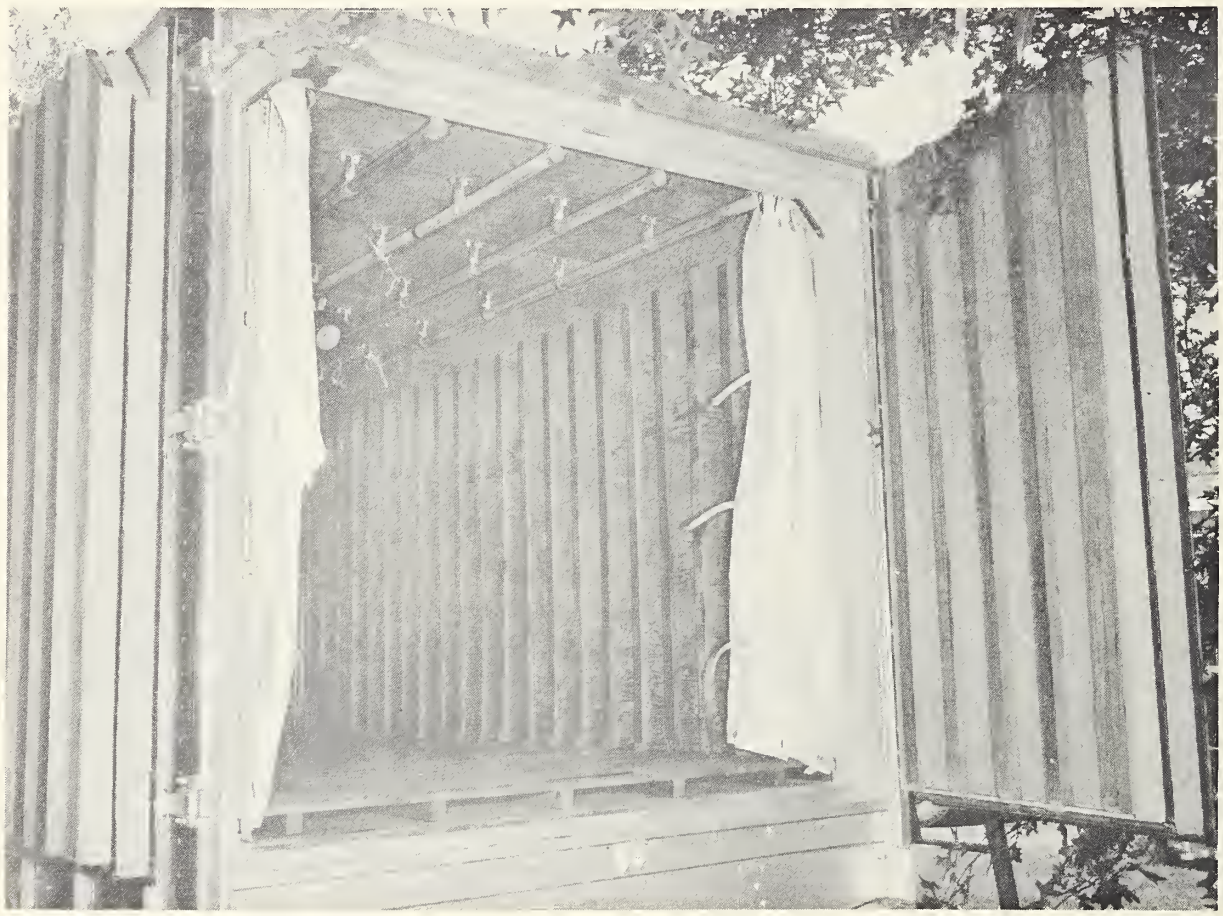

Figure 1.--Rear view of truck-trailer showing floor racks, side wall and door strips, and heavy canvas curtains.

A small door was installed in the curved surface of the right side wall adjacent to the nose of the trailer to permit access to the bunker for icing (fig. 2). The heavy canvas curtains at the rear doors of the trailer, as shown in figure 1, were provided to minimize the loss of refrigeration during loading and unloading operations.

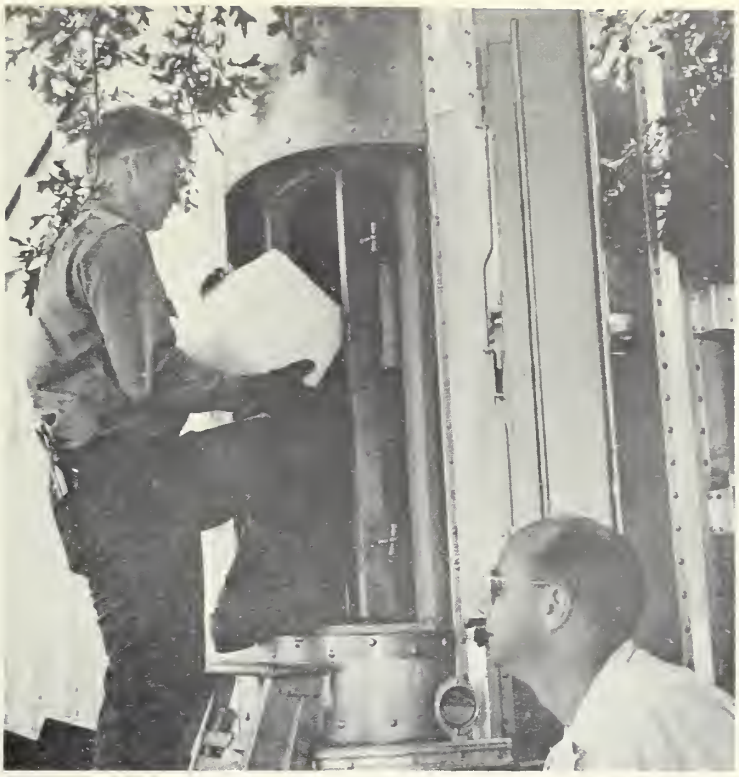

Figure 2.--Door located adjacent to the nose of the trailer to permit access to the ice bunker.

REFRIGERATION SYSTEM

The basic unit of the dry ice system of refrigeration was a welded aluminum ice bunker with a capacity of approximately 900 pounds of dry ice. The unit consisted of finned exterior surfaces, supported by a welded steel frame and enclosed by an outer steel housing (fig. 3). The dry ice was placed on three 1/4-inch aluminum shelves which were welded to the exterior fins to provide maximum conduction of heat. These shelf compartments were sealed by a gasketed access door so that the dry ice would not come in contact with the air in the cargo space. Carbon dioxide, resulting from the sublimation of dry ice, could be released into the cargo space or to the outside by means of appropriate valves.

The circulation of air in the trailer was provided by two blower fans located above the bunker. One fan operated continuously, drawing the air through a bypass in the unit. The other fan—pulling the air from under the floor racks, passing it over the finned surface of the bunker where it was cooled, and then distributing it over the load—cycled on and off automatically from the setting of the thermostat.

The only moving parts in the system were the two blower fans electrically operated from the tractor battery. For lay-overs, an accessory transformer was available for connection to any 110-volt a.c. power source.

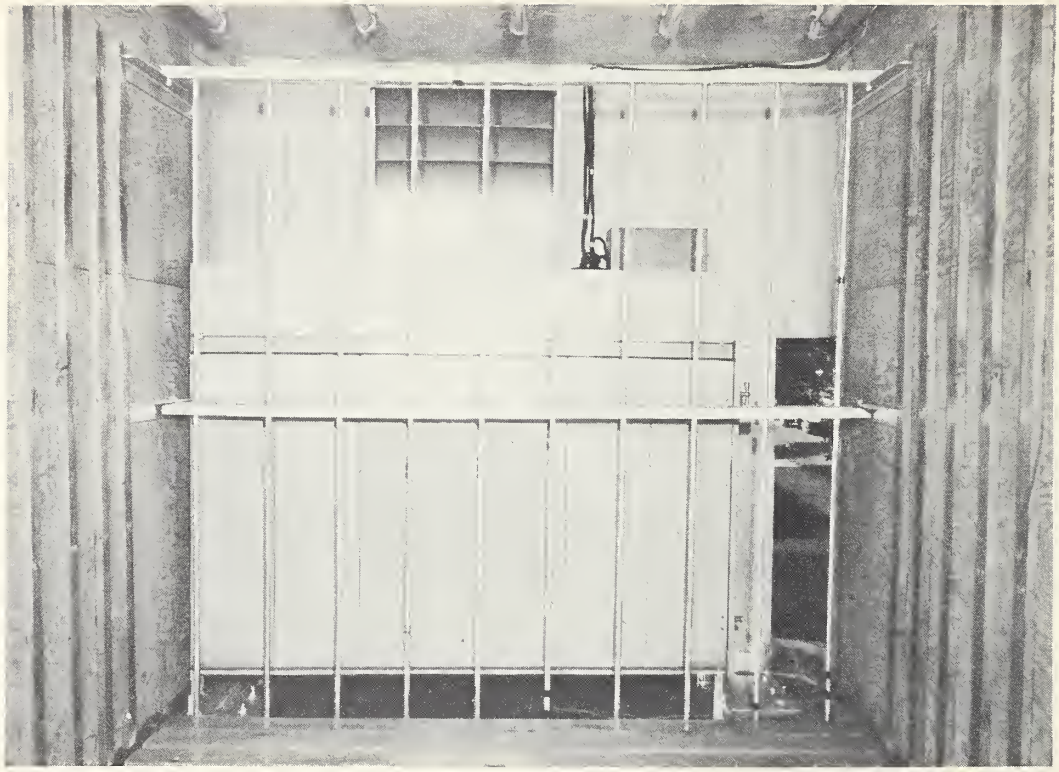

Figure 3.--Refrigerating equipment installed in the nose of the trailer; also, metal bulkhead.

PRELIMINARY PERFORMANCE TEST

Before conducting a series of road tests with the refrigerating unit being tested, a preliminary performance test was conducted at the Department of Agriculture's Plant Industry Station, Beltsville, Md. Prior to the start of this test, the refrigerating unit was iced with approximately 960 pounds of dry ice (18 cakes), and the thermostat was set at 0° F. For the next 24 hours a very close check was kept in order to ascertain the rate of temperature decline at six different locations inside the trailer. Thermocouples which had been previously installed at the six locations enabled the observers to take temperature readings whenever desired without entering the trailer (fig. 4).

Immediately after the air-circulating fans were turned on, temperatures inside the trailer began to drop steadily; however, it was not until 18 hours after the start of the test that temperatures in all six locations registered below zero degrees Fahrenheit. At zero temperature the thermostat automatically shut off the refrigerating fan. Six hours later, when the test was concluded, the average temperature inside the trailer had risen approximately 3° F. with only the circulating fan operating. The dry ice remaining in the bunker was weighed at the conclusion of the test and 170 pounds of the initial charge of 960 pounds

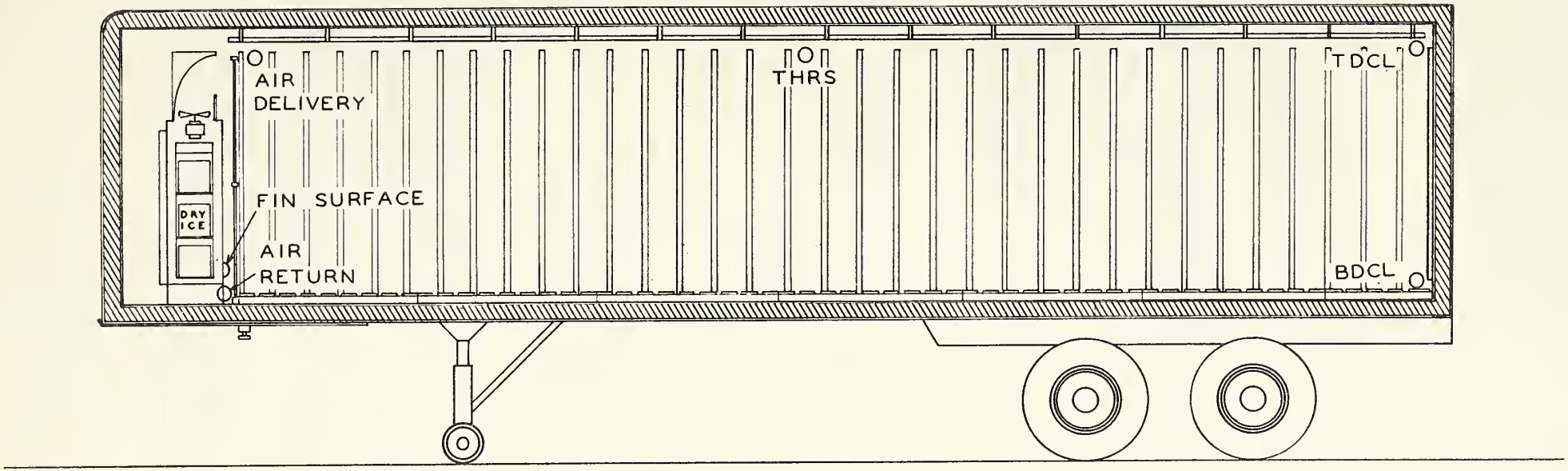

Figure 4.--Diagram of the empty trailer showing the location of the thermocouples used in the preliminary performance test.

still remained in the bunker. The 790 pounds consumed represented sublimation at a rate of approximately 33 pounds per hour for a 24-hour period.

(Detailed temperature information recorded during the preliminary performance test is shown in table 1 and figure 5 in the Appendix.)

TRANSIT TEST PROCEDURE

In preparing the refrigerating equipment for the road tests, a master cable with 12 distance-reading electrical resistance thermometer bulbs was installed in the trailer prior to the initial icing and loading operations. The same trailer and refrigerating equipment were used in all four of the transit tests, and identical procedures were followed. The master cable made it possible to read the air or commodity temperatures in 12 different locations inside the trailer, after loading was completed and the truck doors were closed, by connecting the master cable lead--located just outside the rear door of the trailer--to a reading instrument. Figure 6 in the Appendix shows the locations of the electrical resistance thermometers inside the trailer. Listed below are the locations of the electrical resistance thermometers and their designations:

Location	Designation
Top bunker center line, air	TBCL, air
Bottom door right side, air	BDRS, air
Top bunker center line, commodity	TBCL
Top half right side, commodity	THRS
Top half center line, commodity	THCL
Top door center line, commodity	TDCL
Bottom bunker right side, commodity	BBRS
Bottom bunker center line, commodity	BBCL
Bottom half right side, commodity	BHRS
Bottom half center line, commodity	BHCL
Bottom door center line, commodity	BDCL
Middle half center line, commodity	MHCL

The commodity temperatures were obtained by inserting the thermometer bulbs directly into the frozen citrus concentrate after puncturing the cans. During the loading and unloading operations, commodity temperatures were also taken with mercury hand thermometers in order to check the accuracy of initial and final temperature readings recorded from the electrical resistance thermometers. (See table 2 in the Appendix.) These hand thermometer readings were usually witnessed and verified by a representative of the shipper or receiver.

A representative of the U. S. Department of Agriculture accompanied each test shipment from point of origin to destination, and while the truck was in transit temperatures were read and recorded at intervals of

4 to 6 hours during the entire test period. Icing information was also recorded and a notation was made as to the quantities of dry ice remaining in the bunker at the end of each test.

TRANSIT TESTS

The four tests included in this report, covering truck-trailer loads of frozen citrus concentrate, were as follows: (1) Auburndale, Fla., to San Antonio, Tex.; (2) Plymouth, Fla., to Perth Amboy, N. J.; (3) Plymouth, Fla., to Los Angeles, Calif.; and (4) Corona, Calif., to Orlando, Fla.

Test No. I (Auburndale, Fla., to San Antonio, Tex., Sept. 10-12, 1952)

The outside temperatures during this test ranged from 70° to 94° F. for the 46 hours in transit. Commodity temperatures taken with hand thermometers at the time of loading averaged -6° F. At destination, just prior to unloading, the final temperatures recorded from the electrical resistance thermometers showed an average of -1.5° on top of the load and an average of -1.3° F. on the bottom of the load.

The refrigerating unit was initially iced with 810 pounds of dry ice and re-iced with 710 pounds in transit, making a total of 1,520 pounds of dry ice furnished. An estimated 320 pounds of dry ice remained in the ice bunker when the test was concluded, making a total consumption of 1,200 pounds. Therefore, the average hourly rate of consumption of dry ice during the test was approximately 26 pounds.

(Detailed temperature information is shown in table 3 and figs. 7 and 8 in the Appendix.)

Test No. II (Plymouth, Fla., to Perth Amboy, N. J., Sept. 17-19, 1952)

The outside temperatures during this test ranged from 70° to 95° F. Commodity temperatures taken with hand thermometers during loading averaged 0° F. Final temperatures recorded from the electrical resistance thermometers at destination 50½ hours later, showed an average of 3.8° on top of the load and 2.7° F. on the bottom of the load.

The refrigerating unit was initially iced with 908 pounds of dry ice at Plymouth, Fla., and re-iced once in transit with 450 pounds, making a total of 1,358 pounds of dry ice furnished. On arrival at destination, it was estimated that 150 pounds of dry ice remained in the ice bunker, making a total of 1,208 pounds consumed during the test, or an hourly consumption rate of approximately 24 pounds.

Because of a mechanical failure of the tractor, the air-circulating fans of the dry ice unit did not operate for 1 hour during the test.

(Detailed temperature information is shown in table 4 and figs. 9 and 10 in the Appendix.)

Test No. III (Plymouth, Fla., to Los Angeles, Calif., Sept. 26-30, 1952)

This was the first transcontinental refrigerated truck-trailer test conducted by the Department of Agriculture. The outside temperatures ranged from 58° to 98° F. during the test.

Commodity temperatures taken with hand thermometers as the trailer was being loaded ranged from -2° to -4° F., averaging -3° F.

On arrival at Los Angeles, Calif., 90 hours later, commodity temperatures recorded from the electrical resistance thermometers showed an average of 2.3° on top of the load and an average of 3.8° F. on the bottom of the load.

The refrigerating unit was initially iced at Plymouth, Fla., with 825 pounds of dry ice, re-iced in transit at Shreveport, La., with 900 pounds, and at Tucson, Ariz., with an additional 600 pounds, making a total of 2,325 pounds furnished. An estimated 500 pounds remained in the bunker when the test was concluded, making a total of 1,825 pounds of dry ice consumed, or an hourly rate of consumption of approximately 20 pounds.

(Detailed temperature information is shown in table 5 and figs. 11 and 12 in the Appendix.)

Test No. IV (Corona, Calif., to Orlando, Fla., Oct. 6-10, 1952)

In Test No. IV, commodity temperatures rose considerably while the refrigerating unit was turned off during loading operations and also at one point during the test, when the driver miscalculated his ice requirements and permitted the refrigerating unit to operate for an extended period with an insufficient supply of dry ice in the bunker. As a result of these two complications, very little information was gained from the test concerning the dry ice consumption or the refrigerating efficiency of the unit. However, results did point out very definitely the tendency of the air temperatures inside the trailer to rise as the quantity of dry ice in the bunker decreased, clearly indicating the absolute necessity of keeping a sufficient supply of dry ice in the bunker at all times. Commodity temperatures, recorded from the electrical resistance thermometers immediately after loading was completed, averaged 6.0° F.

At the completion of the test 93 hours later, the average of the commodity temperatures was 3.4° F. The total amount of dry ice consumed was 1,545 pounds, with 400 pounds remaining in the bunker at the end of the test period.

For the reasons previously stated, this test was not included in Results of Tests. (See table 6 and figs. 13 and 14 in the Appendix for complete temperature information.)

COST AND AVAILABILITY OF DRY ICE

Throughout the test periods, purchases of dry ice were made only through normal channels available to the general public. Except in one instance, no difficulty was encountered in obtaining dry ice in sufficient quantities to operate the refrigerating unit satisfactorily. The price generally paid for dry ice was 3.1 cents per pound, which was the usual discount rate for quantity purchases.

DRY ICE CONSUMPTION

The quantity of dry ice consumed in the first three transit tests averaged 23.3 pounds per hour. In test No. IV, the ice consumption rate was only about 17 pounds per hour. This was considerably below average owing to the fact that the dry ice in the refrigerating unit became exhausted, because of the miscalculation mentioned previously. As shown in table 6 in the Appendix, both commodity and air temperatures were relatively high just prior to re-icing at Abilene, Tex., indicating very clearly that the first re-icing for test No. IV should have taken place sooner. The sharp temperature rise is graphically illustrated in figures 13 and 14.

(See table 7 in the Appendix for complete icing information pertaining to all four of the tests.)

RESULTS OF TESTS

Preliminary Performance Test

Results of the preliminary performance test showed that approximately 18 hours were required to reduce the average air temperature inside the empty trailer from 57° to 0° F. The dry ice consumption rate was relatively high, with 790 pounds out of a total supply of 960 being consumed during the 24-hour test period. The consumption rate per hour was approximately 33 pounds.

Transit Tests

The average temperature rise for tests No. I, No. II, and No. III, was 5.6° F. with average loading and unloading temperatures of -4.0° and 1.6° F., respectively, for the three transit tests. The average dry ice consumption rate for the three tests was 23.3 pounds per hour, ranging from 20 to 26 pounds.

It should be pointed out here that the heavy canvas curtains provided at the rear doors of the test trailer should not be closed during transportation, since closing the curtains would curtail the circulation of air around the load and nullify any benefit derived from the vertical strips nailed to the rear doors.

Mention should also be made of the fact that temperatures of the commodity located in the top and end positions in the load will show a sharp rise if unloading is not started immediately after the trailer doors are opened at destination. This point is shown clearly in Test No. II where the commodity temperature at the top door center line position rose from 4.5° F., recorded on arrival, to 11° F., 2 hours later, when unloading finally started.

Throughout the test periods no mechanical defects pertaining to the refrigerating system were encountered and, except in one instance, a sufficient supply of dry ice was available to maintain the refrigerating system satisfactorily.

APPENDIX

Table 1.--Temperatures recorded during preliminary performance test with truck-trailer equipped with dry ice system of refrigeration at Beltsville, Md., August 26-27, 1952

Date 1952	Time	Outside temperature	Location of thermometer bulb					
			TDCL	THRS	BDCL	Return air	Delivery air	Fin temperature
		°F.	°F.	°F.	°F.	°F.	°F.	°F.
8-26	10:56 a.m.	74.0	67.5	67.5	67.5	69.5	70.5	70.5
8-26	10:57 a.m.	74.0	Initially iced before loading with 962 pounds of dry ice					
8-26	11:08 a.m.	74.0	Air-circulating fans started					
8-26	11:15 a.m.	74.5	61.0	61.0	63.5	61.0	53.5	47.5
8-26	11:30 a.m.	75.0	58.5	58.0	61.0	55.5	46.0	40.0
8-26	11:45 a.m.	75.5	54.0	55.5	57.0	52.0	42.5	37.0
8-26	12:01 p.m.	76.0	49.0	50.5	51.0	47.5	38.5	33.5
8-26	12:15 p.m.	77.5	48.5	50.5	52.0	46.5	37.0	31.5
8-26	12:30 p.m.	77.5	44.5	46.5	48.0	43.5	34.5	29.0
8-26	12:45 p.m.	78.0	45.0	46.5	45.5	42.0	32.5	27.5
8-26	1:00 p.m.	81.0	42.0	44.5	44.5	41.0	31.0	26.0
8-26	1:30 p.m.	81.0	40.0	41.5	39.5	37.5	28.0	23.0
8-26	2:00 p.m.	82.0	36.5	39.0	37.0	36.0	26.0	21.0
8-26	2:30 p.m.	82.5	35.5	37.5	35.5	32.5	23.5	19.0
8-26	3:00 p.m.	83.0	31.5	34.5	31.5	30.0	21.0	17.0
8-26	3:30 p.m.	86.0	28.5	32.0	30.0	27.5	17.5	14.5
8-26	4:00 p.m.	84.0	27.0	31.5	28.0	25.5	16.5	13.5
8-26	4:30 p.m.	85.0	24.5	28.0	25.0	23.5	14.5	12.0
8-26	5:00 p.m.	82.0	23.0	26.5	22.5	21.5	13.0	10.0
8-26	5:30 p.m.	83.0	20.5	22.5	21.5	20.5	11.5	9.0
8-26	6:00 p.m.	84.0	21.5	23.5	21.0	19.0	10.5	8.5
8-26	6:30 p.m.	81.0	19.5	23.0	20.5	18.5	10.0	8.0
8-26	7:00 p.m.	80.5	17.5	21.0	19.5	16.5	9.0	6.5
8-26	7:30 p.m.	80.5	16.5	20.0	16.5	15.0	7.5	5.0
8-26	8:00 p.m.	76.0	15.0	18.0	15.0	14.0	6.5	3.5
8-26	8:30 p.m.	74.0	14.0	16.0	14.0	12.0	5.0	2.5
8-26	9:00 p.m.	72.0	11.5	15.0	12.0	10.5	3.5	1.0
8-26	10:00 p.m.	69.0	8.5	12.5	9.5	8.0	1.0	-1.5
8-26	11:00 p.m.	66.0	6.5	9.5	7.0	5.5	-1.5	-4.0
8-27	12:01 a.m.	65.0	3.0	4.5	5.5	2.0	-4.5	-6.5
8-27	1:00 a.m.	64.0	2.0	4.0	2.5	0.5	-5.5	-8.0
8-27	2:00 a.m.	64.0	1.0	3.5	1.0	-1.5	-7.0	-9.0
8-27	3:00 a.m.	62.0	-0.5	0.5	0	-2.0	-8.0	-10.0
8-27	4:00 a.m.	61.0	-2.0	0.5	-1.0	-3.5	-9.0	-11.7
8-27	5:00 a.m.	59.0	-2.0	-1.0	-2.5	-3.5	-10.0	-14.0
8-27	5:20 a.m.	59.0	Thermostat shut off the refrigeration fan					
8-27	6:00 a.m.	60.0	2.0	2.5	0	-5.5	-13.5	-17.5
8-27	7:00 a.m.	60.0	2.5	2.5	0	-5.5	-13.5	-17.5
8-27	8:00 a.m.	61.0	3.0	1.0	0.5	-6.0	-13.5	-17.0
8-27	9:00 a.m.	68.0	3.5	3.0	0.5	-5.5	-13.5	-17.0
8-27	9:42 a.m.	70.0	Bunker check; estimated 200 pounds dry ice remained					
8-27	10:00 a.m.	73.0	4.0	5.0	1.0	-4.5	-11.0	-15.5
8-27	11:00 a.m.	76.0	5.5	6.0	3.0	-2.5	-10.5	-14.5
8-27	11:07 a.m.	76.0	Unit shut off; doors opened; 170 pounds dry ice remained					

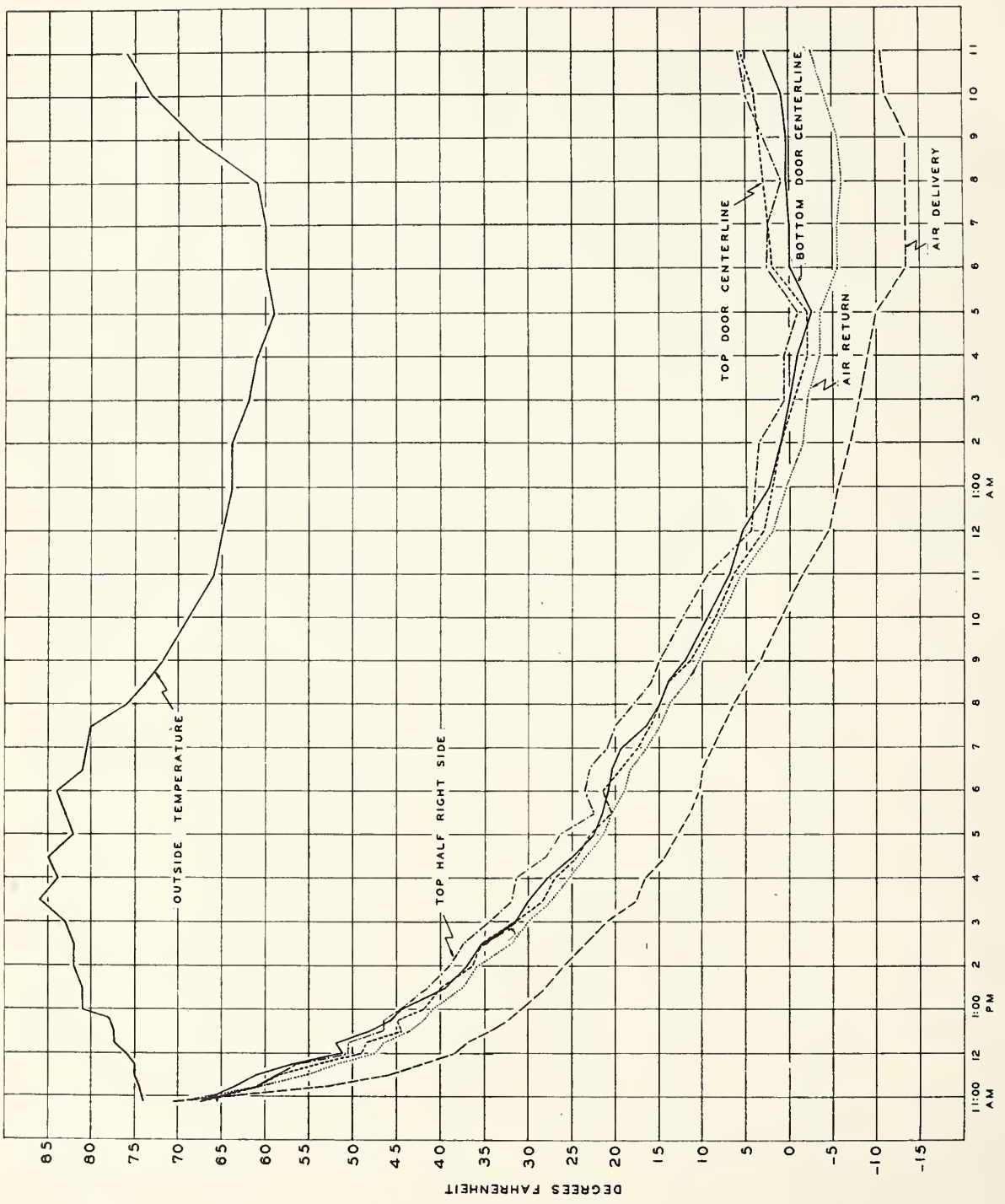

Figure 5.--Air temperatures recorded during the preliminary performance test, with the empty trailer, at Beltsville, Md.

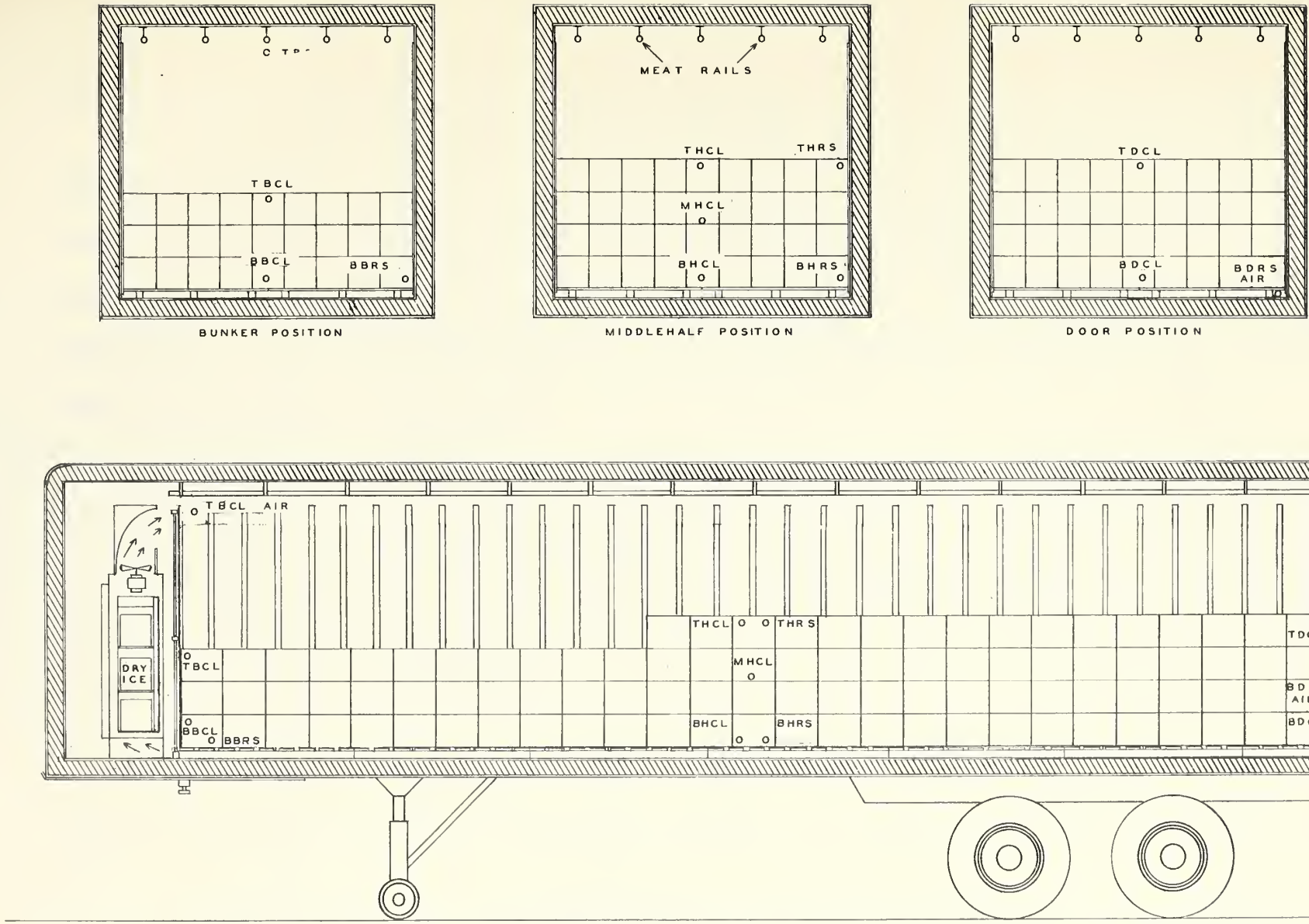

Figure 6.--Diagram of the trailer showing the component parts of the refrigerating system and also the locations of the electrical resistance thermometers during the transit tests. (For explanation of TBCL, BBCL, etc., see page 6.)

Table 2.--Commodity temperatures at specified locations in the truck-trailer, according to hand thermometers, at times of loading and unloading each of the four test shipments

Location	Temperature of commodity in test shipment											
	Auburndale, Fla. to San Antonio, Tex.			Plymouth, Fla. to Perth Amboy, N. J.			Plymouth, Fla. to Los Angeles, Calif.			Corona, Calif. to Orlando, Fla.		
	Loading	Unloading	Temperature rise	Loading	Unloading	Temperature rise	Loading	Unloading	Temperature rise	Loading	Unloading	Temperature rise
	°F	°F.	°F.	°F	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
TECL	-6	-1	5	-1	6	7	-2	0	2	-4	6	10
THRS	-7	-2	5	0	7	7	-3	5	8	-2	4	6
THCL	-7	-1	6	-1	6	7	-3	0	3	-4	4	8
TDCL	-5	-1	4	0	11	11	-4	7	11	-4	2	6
BBRS	-7	-1	6	0	8	8	-3	3	6	-4	8	12
BBCL	-7	0	7	0	5	5	-3	4	7	-4	6	10
BHRS	-6	2	8	0	5	5	-3	4	7	-4	5	9
BHCL	-7	-1	6	0	3	3	-3	5	8	-4	5	9
BDCL	-5	-2	3	0	6	6	-3	4	7	-4	4	8
Average	-6	-1	5	0	6	6	-3	4	7	-4	5	9

Note: Hand thermometer temperatures at time of unloading were taken after the commodity had been removed from the trailer to the dock. Consequently, these temperatures are slightly higher than the last electrical resistance thermometer readings taken before the trailer doors were opened.

Table 3.--Temperatures recorded during transit test with truck-trailer, equipped with dry ice system of refrigeration, from Auburndale, Fla., to San Antonio, Tex., September 10-12, 1952

Place	Date 1952	Time	Out-side temp.	Air temperature		Commodity temperature									Top commodity			Bottom commodity		
				TBCL 1/	BDRS	TBCL	THRS	THCL	TDCL	BBRS	BBCL	BHRS	BHCL	BDCL	Max.	Min.	Av.	Max.	Min.	Av.
			°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
						Initially iced before loading with 810 pounds of dry ice														
Auburndale, Fla.	9-10	11:00 a.m.	81	Loading started																
Auburndale, Fla.	9-10	12:01 p.m.	82	Loading completed																
Auburndale, Fla.	9-10	12:25 p.m.	82	38.5	42.5	-7.3	-7.5	-8.7	-7.5	-6.5	-7.0	-7.2	-9.5	-5.2	-7.3	-8.7	-7.8	-5.2	-9.5	-7.1
Fanning Springs, Fla.	9-10	5:45 p.m.	83	1.5	2.5	-4.3	-4.5	-3.7	-4.5	-3.5	-5.0	-5.2	-6.5	-4.2	-3.7	-4.5	-4.3	-3.5	-6.5	-4.9
Panama City, Fla.	9-11	12:01 a.m.	77	-3.5	-1.5	-2.3	-4.5	-3.7	-3.5	-2.5	-3.0	-4.2	-6.5	-4.2	-2.3	-4.5	-3.5	-2.5	-6.5	-4.1
Mobile, Ala.	9-11	5:15 a.m.	70	-2.5	-0.5	-2.3	-3.5	-3.7	-3.5	-1.5	-2.0	-3.2	-6.5	-4.2	-2.3	-3.7	-3.3	-1.5	-6.5	-3.5
Slidell, La.	9-11	9:22 a.m.	79	-1.5	0.5	-2.3	-3.5	-2.7	-3.5	-0.5	-2.0	-3.2	-6.5	-3.2	-2.3	-3.5	-3.0	-0.5	-6.5	-3.1
Baton Rouge, La.	9-11	1:37 p.m.	92	6.5	8.5	-2.3	-2.5	-2.7	-2.5	0.5	-1.0	-2.2	-5.5	-2.2	-2.3	-2.7	-2.5	0.5	-5.5	-2.1
Baton Rouge, La.	9-11	3:00 p.m.	94	Re-iced with 710 pounds of dry ice																
Baton Rouge, La.	9-11	5:40 p.m.	90	0.5	5.5	-2.3	-3.5	-2.7	-2.5	-0.5	-2.0	-3.2	-6.5	-3.2	-2.3	-3.5	-2.8	-0.5	-6.5	-3.1
De Quincy, La.	9-11	9:15 p.m.	78	-5.5	-0.5	-2.3	-2.5	-2.7	-2.5	0.5	-2.0	-2.2	-6.5	-3.2	-2.3	-2.7	-2.5	0.5	-6.5	-2.7
Houston, Tex.	9-12	2:52 a.m.	80	-5.5	-1.5	-1.3	-1.5	-1.7	-1.5	1.5	0.0	-2.2	-4.5	-2.2	-1.3	-1.7	-1.5	1.5	-4.5	-1.5
San Antonio, Tex.	9-12	8:30 a.m.	71	-3.5	-0.5	-1.3	-1.5	-1.7	-1.5	1.5	0.0	-1.2	-4.5	-2.2	-1.3	-1.7	-1.5	1.5	-4.5	-1.3
San Antonio, Tex.	9-12	8:40 a.m.	71	Estimated 320 pounds of dry ice remained																
San Antonio, Tex.	9-12	9:15 a.m.	72	Unloading started																
San Antonio, Tex.	9-12	10:50 a.m.	72	Unloading completed																

1/ For explanation of thermometer locations, see page 6.

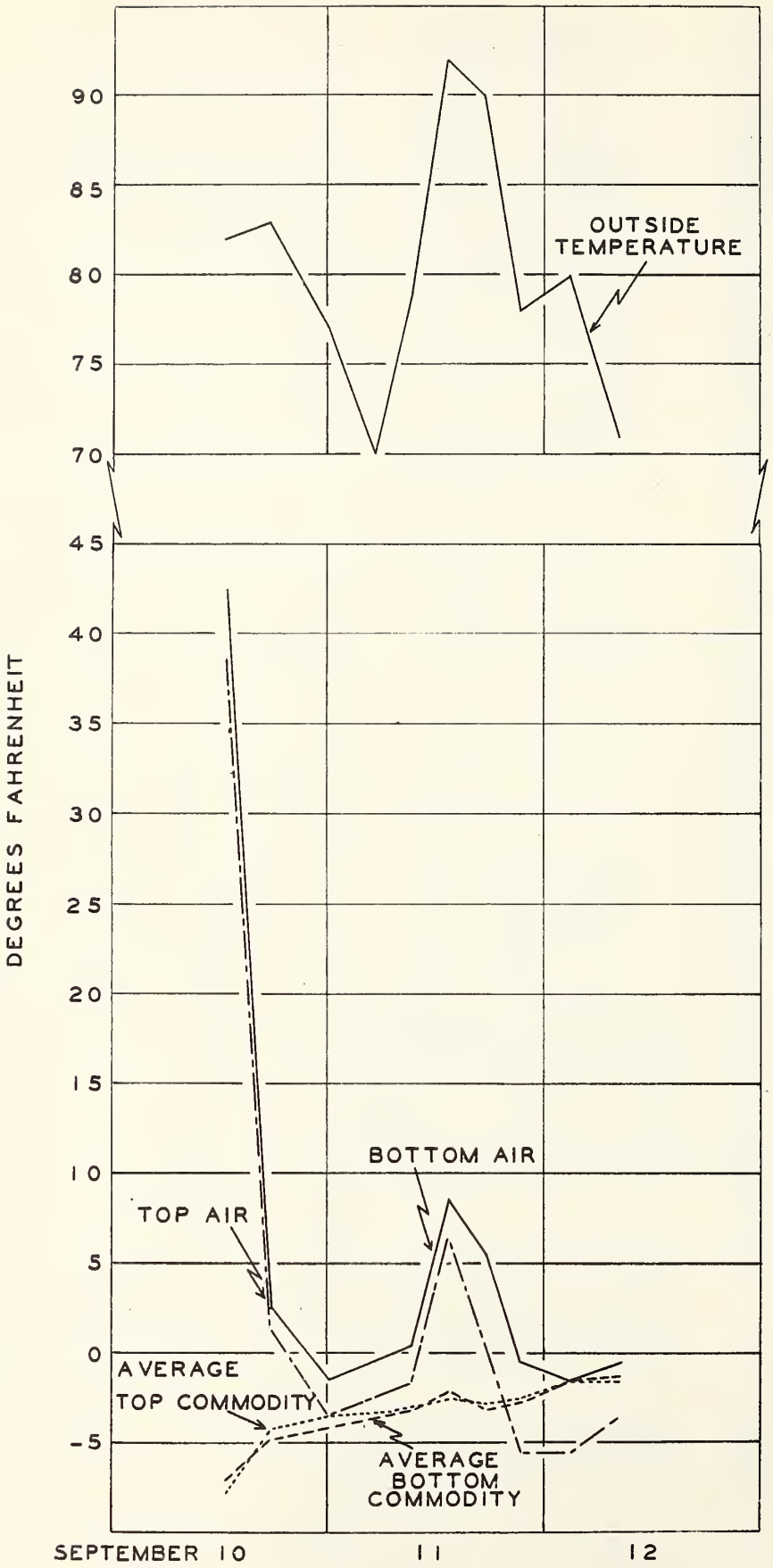

Figure 7.--Air and commodity temperatures during transit test No. I. (Auburndale, Fla., to San Antonio, Tex.)

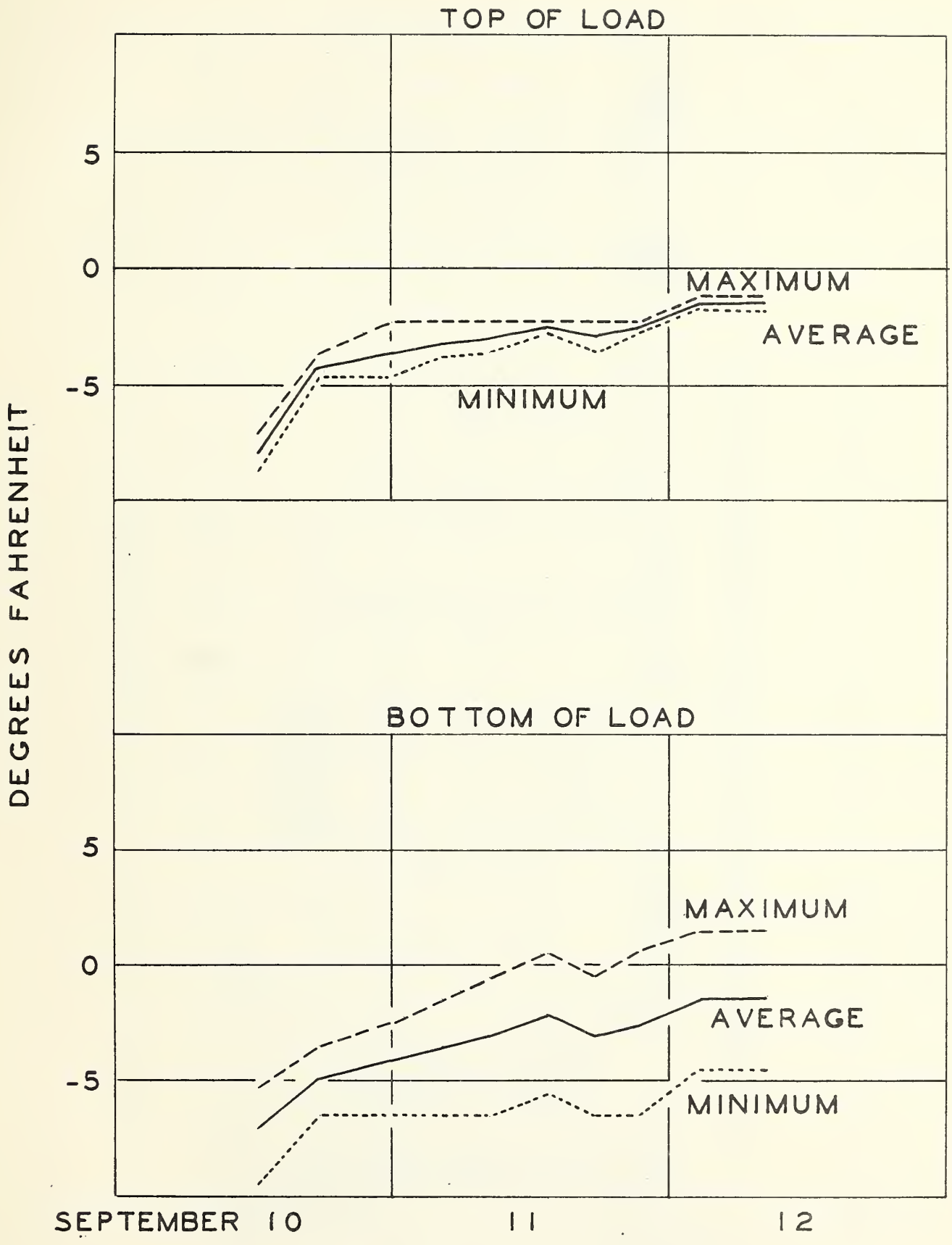

Figure 8.--Commodity temperatures at the top and bottom of the load in test No. I. (Auburndale, Fla., to San Antonio, Tex.)

Table 4.--Temperatures recorded during transit test with truck-trailer, equipped with dry ice system of refrigeration, from Plymouth, Fla., to Perth Amboy, N. J., September 17-19, 1952

Place	Date 1952	Time	Out-side temp.	Air temperature		Commodity temperature									Top commodity			Bottom commodity		
				TBCL 1/	BDRS	TBCL	THRS	THCL	TDCL	BDRS	BBCL	BHRS	BHCL	BDCL	Max.	Min.	Av.	Max.	Min.	Av.
			°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
						Initially iced before loading with 908 pounds of dry ice														
Plymouth, Fla.	9-17	11:20 a.m.	91			Loading started														
Plymouth, Fla.	9-17	12:10 p.m.	92			Loading completed														
Plymouth, Fla.	9-17	12:15 p.m.	92	50.0	57.5	0.7	0.5	-0.3	-1.5	1.5	0.0	-0.2	-2.5	-0.2	0.7	-1.5	-0.2	1.5	-2.5	-0.3
Ocala, Fla.	9-17	2:40 p.m.	95	8.0	16.5	2.7	3.5	1.3	1.5	2.5	0.0	0.8	-0.5	0.8	3.5	1.3	2.3	2.5	-0.5	0.7
Callahan, Fla.	9-17	5:30 p.m.	85	3.0	11.5	4.7	6.5	3.3	3.5	4.5	2.0	1.8	0.5	2.8	6.5	3.3	4.5	4.5	0.5	2.3
Nahunta, Ga.	9-17	7:45 p.m.	80	0.0	8.5	3.7	4.5	2.3	2.5	3.5	1.0	0.8	-0.5	1.8	4.5	2.3	3.3	3.5	-0.5	1.3
Claxton, Ga.	9-17					Unit off 9:45 p.m. to 10:45 p.m. due to tractor breakdown														
Claxton, Ga.	9-17	11:15 p.m.	76	-1.0	5.5	1.7	3.5	1.3	1.5	3.5	0.0	-0.2	-1.5	0.8	3.5	1.3	2.0	3.5	-1.5	0.5
Bamberg, S. C.	9-18	5:45 a.m.	71	10.0	8.5	1.7	2.5	1.3	2.5	4.5	0.0	0.8	-1.5	0.8	2.5	1.3	2.0	4.5	-1.5	0.9
Sumter, S. C.	9-18	9:00 a.m.	82	0.0	6.5	1.7	1.5	0.3	1.5	3.5	0.0	0.8	-1.5	0.8	1.7	0.3	1.3	3.5	-1.5	0.7
Laurinburg, N. C.	9-18	12:45 p.m.	90	4.0	8.5	1.7	2.5	1.3	1.5	4.5	0.0	0.8	-1.5	1.8	2.5	1.3	1.8	4.5	-1.5	1.1
Fayettsville, N. C.	9-18	7:10 p.m.	83	5.0	10.5	1.7	3.5	1.3	1.5	4.5	0.0	1.8	-1.5	1.8	3.5	1.3	2.0	4.5	-1.5	1.3
Richmond, Va.	9-18	10:00 p.m.	70			Re-iced with 450 pounds of dry ice														
Richmond, Va.	9-18	10:15 p.m.	70	9.0	10.5	3.7	4.5	3.3	3.5	5.5	1.0	1.8	-1.5	2.8	4.5	3.3	3.8	5.5	-1.5	1.9
New Castle, Del.	9-19	8:20 a.m.	76	-1.0	5.5	3.7	4.5	3.3	3.5	6.5	1.0	2.8	-0.5	3.8	4.5	3.3	3.8	6.5	-0.5	2.7
Perth Amboy, N. J.	9-19	11:45 a.m.	73	1.0	7.5	2.7	4.5	3.3	4.5	5.5	2.0	2.8	-0.5	3.8	4.5	2.7	3.8	5.5	-0.5	2.7
Perth Amboy, N. J.	9-19					Estimated 150 pounds of dry ice remained														
Perth Amboy, N. J.	9-19	1:45 p.m.	71			Unloading started														
Perth Amboy, N. J.	9-19	3:00 p.m.	73			Unloading completed														

1/ For explanation of thermometer locations, see page 6.

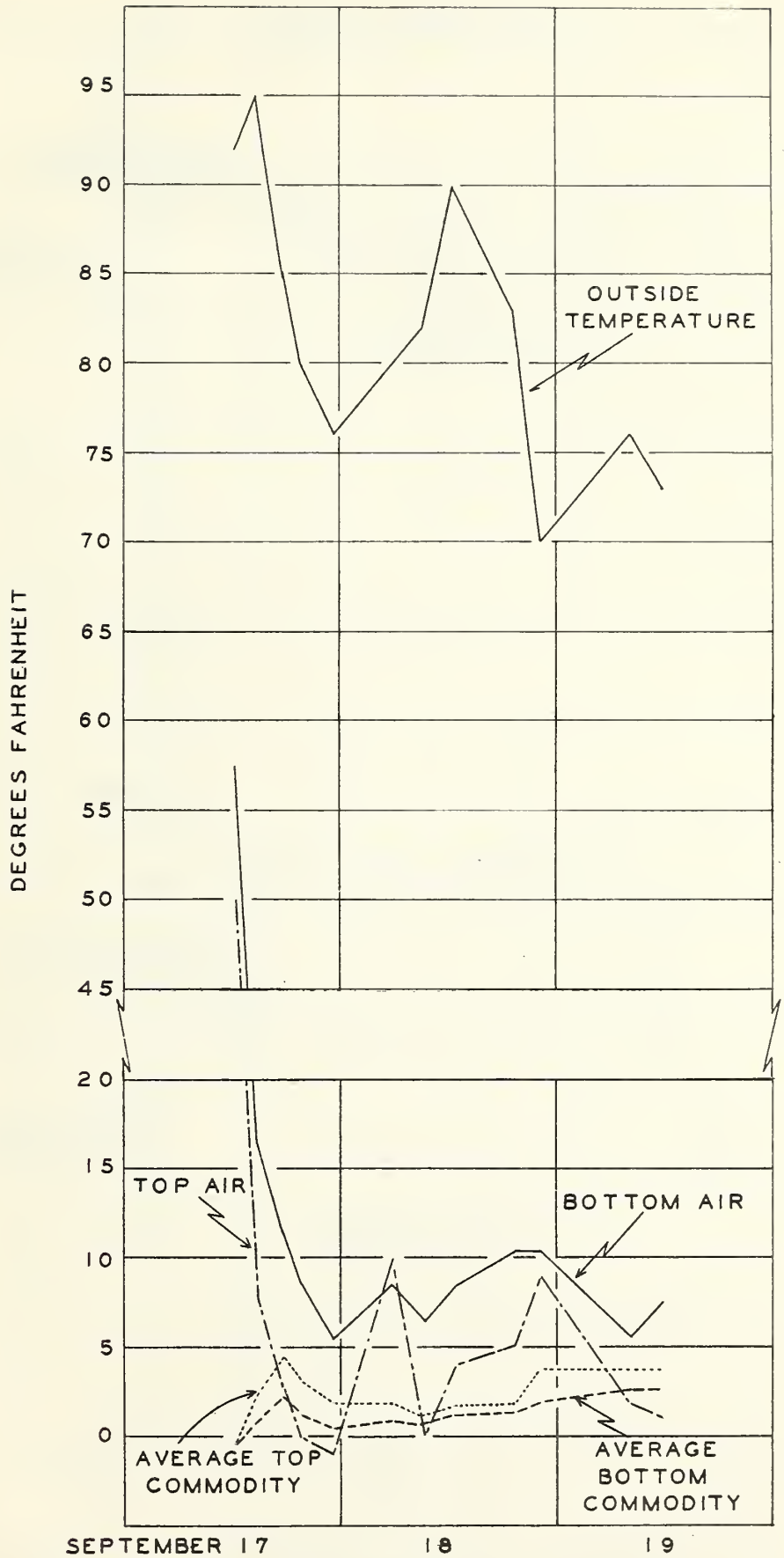

Figure 9.--Air and commodity temperatures during transit test No. II. (Plymouth, Fla., to Perth Amboy, N. J.)

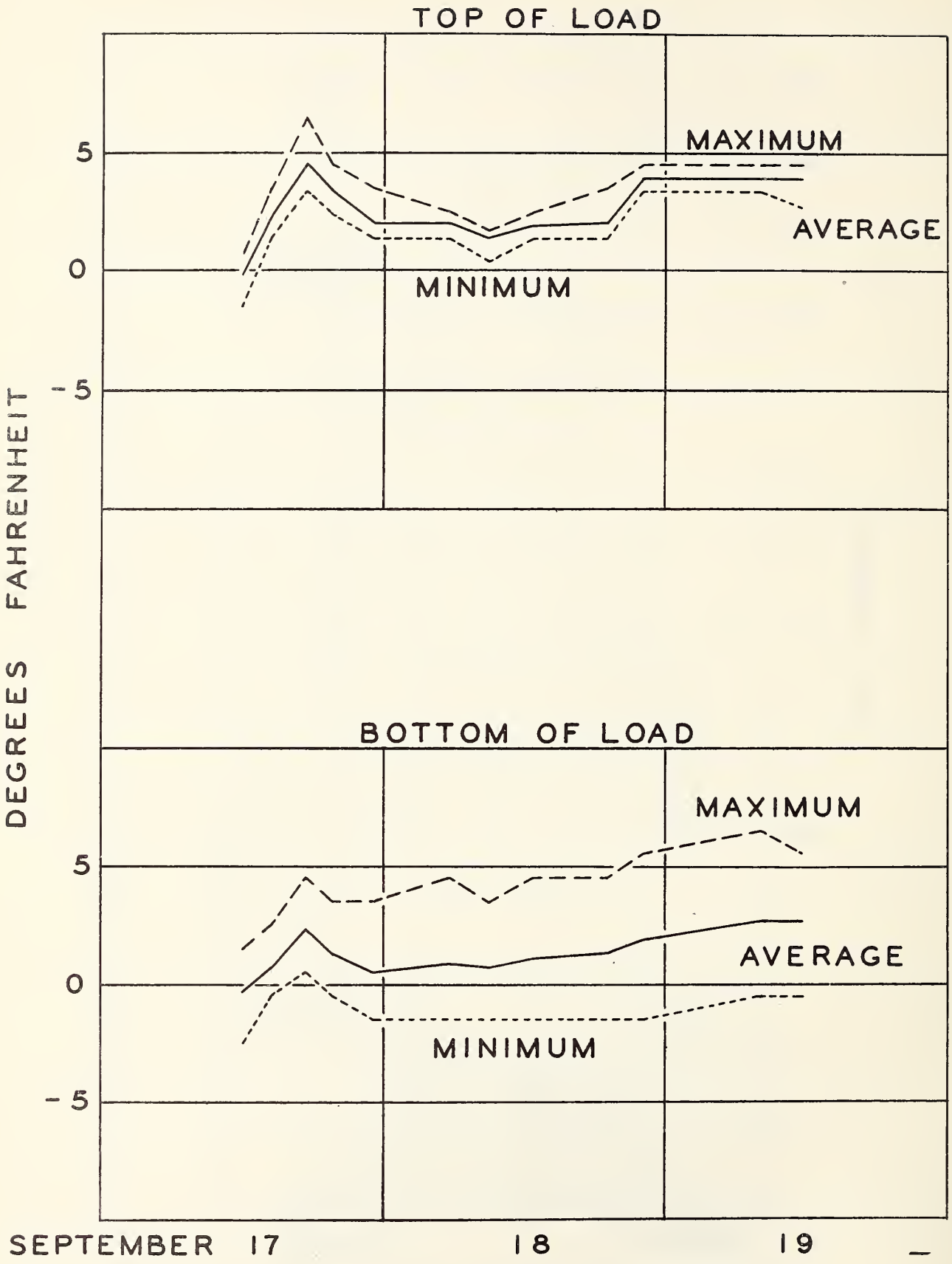

Figure 10.--Commodity temperatures at the top and bottom of the load in test No. II. (Plymouth, Fla., to Perth Amboy, N. J.)

Table 5.--Temperatures recorded during transit test with truck-trailer, equipped with dry ice system of refrigeration, from Plymouth, Fla., to Los Angeles, Calif., September 26-30, 1952

Place	Date 1952	Time	Outside temp.	Air temperature		Commodity temperature										Top commodity			Bottom commodity		
				TBCL 1/	BDRS	TBCL	THRS	THCL	TDCL	MHCL	BBRS	BBCL	BHRS	BHCL	BDCL	Max.	Min.	Av.	Max.	Min.	Av.
			°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
						Initially iced before loading with 825 pounds of dry ice															
Plymouth, Fla.	9-26	2:15 p.m.	74			Loading started															
Plymouth, Fla.	9-26	3:10 p.m.	76			Loading completed															
Plymouth, Fla.	9-26	3:55 p.m.	78	73	57	-4	-5	-3	2/ -	-4	-4	-3	-5	-6	-5	-3	-5	-4.0	-3	-6	-4.6
Leesburg, Fla.	9-26	5:30 p.m.	78	43	16	-3	-3	0	-	-4	-3	-2	-4	-6	-5	0	-3	-2.0	-2	-6	-4.0
Tallahassee, Fla.	9-27	12:30 a.m.	72	-4	4	-2	0	2	-	-3	2	0	-2	-4	-2	2	-2	0.0	2	-4	-1.2
Fort Walton, Fla.	9-27	6:25 a.m.	62	-3	5	0	-1	0	-	-3	2	-1	-2	-4	-2	0	-1	-0.3	2	-4	-1.4
Collins, Miss.	9-27	12:55 p.m.	85	2	9	0	-1	0	-	-3	3	0	-2	-4	-2	0	-1	-0.3	3	-4	-1.0
Shreveport, La.	9-27	9:00 p.m.	71			Re-iced with 900 pounds of dry ice															
Shreveport, La.	9-27	9:15 p.m.	71	8	1	0	0	2	-	0	4	2	-1	-2	0	2	0	0.7	4	-2	0.6
Marshall, Tex.	9-28	1:15 a.m.	68	-10	4	2	0	2	-	-2	2	4	0	-2	0	2	0	1.3	4	-2	0.8
Ranger, Tex.	9-28	8:35 a.m.	73	-11	3	-1	0	0	-	-2	4	3	0	-2	0	0	-1	-0.3	4	-2	1.0
Sweetwater, Tex.	9-28	12:35 p.m.	92	-4	7	-2	-2	-2	-	-2	3	2	0	-3	0	-2	-2	-2.0	3	-3	0.4
Odessa, Tex.	9-28	4:30 p.m.	94	-2	6	-2	-1	-2	-	-2	3	2	0	-3	0	-1	-2	-1.7	3	-3	0.4
El Paso, Tex.	9-28	11:40 p.m.	72	0	10	-2	0	0	-	-2	5	2	0	-2	0	0	-2	-0.7	5	-2	1.0
Lordsburg, N. Mex.	9-29	7:00 a.m.	58	0	8	-1	0	0	-	-1	5	3	-1	-2	0	0	-1	-0.3	5	-2	1.0
Tucson, Ariz.	9-29	11:30 a.m.	96	1	12	1	0	0	-	-1	5	3	0	-2	-1	1	0	0.3	5	-2	1.0
Tucson, Ariz.	9-29	11:45 a.m.				Re-iced with 600 pounds of dry ice															
Gila Bend, Ariz.	9-29	4:30 p.m.	98	4	13	2	1	2	-	0	6	4	1	-2	1	2	1	1.7	6	-2	2.0
El Centro, Calif.	9-29	10:00 p.m.	88	6	14	3	2	3	-	0	6	4	2	1	2	3	2	2.7	6	1	3.0
Los Angeles, Calif.	9-30	3:50 a.m.	70	4	12	3	3	4	-	0	8	6	3	0	2	4	3	3.3	8	0	3.8
Los Angeles, Calif.	9-30	8:00 a.m.	65	7	12	3	2	2	-	0	8	5	3	0	3	3	2	2.3	8	0	3.8
Los Angeles, Calif.	9-30	8:30 a.m.	68			Estimated 500 pounds of dry ice remained															
Los Angeles, Calif.	9-30	8:30 a.m.	68			Unloading started															
Los Angeles, Calif.	9-30	9:45 a.m.	--			Unloading completed															

1/ For explanation of thermometer locations, see page 6.
2/ Thermometer out of order.

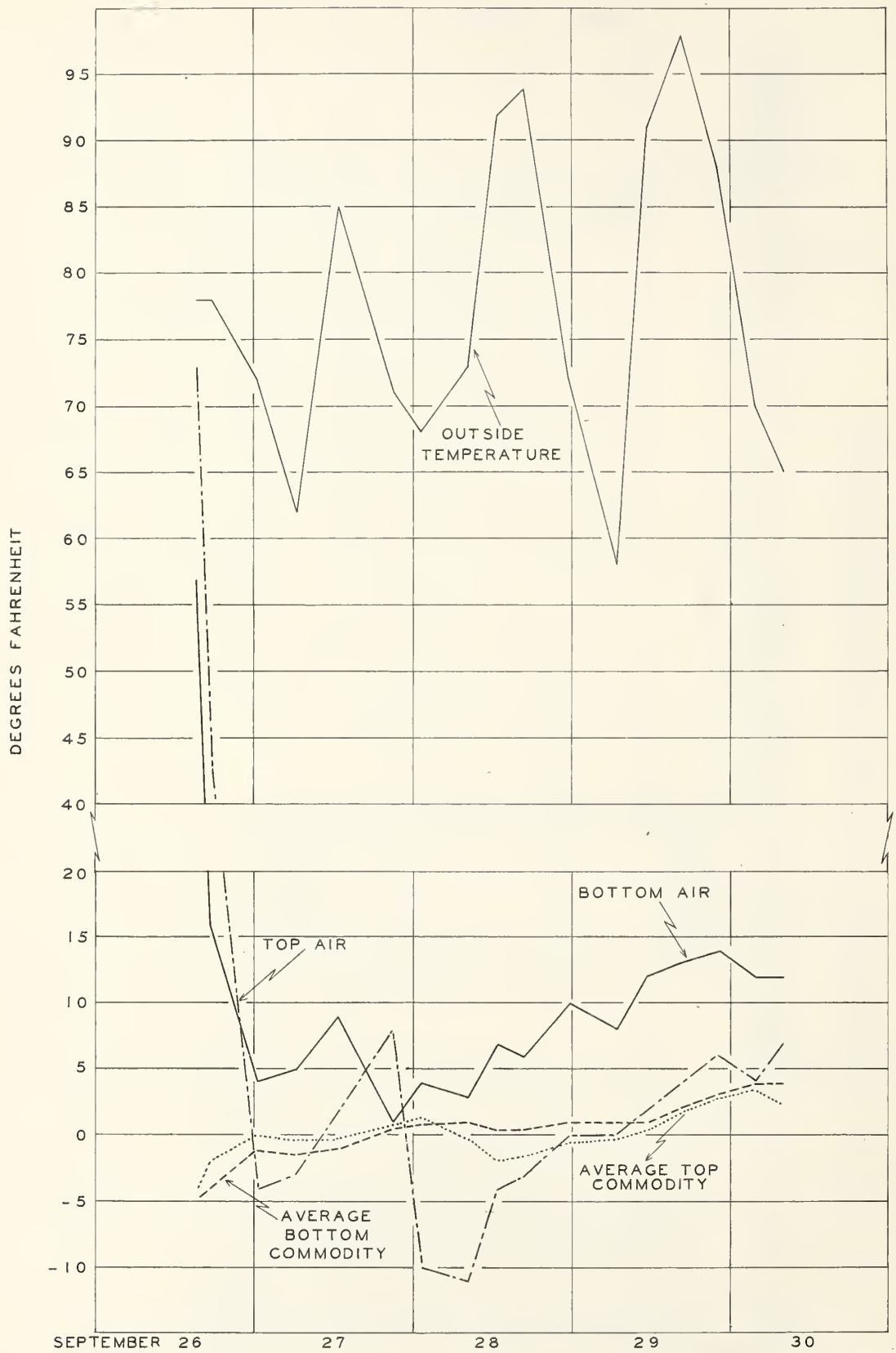

Figure 11.--Air and commodity temperatures during transit test No. III. (Plymouth, Fla., to Los Angeles, Calif.)

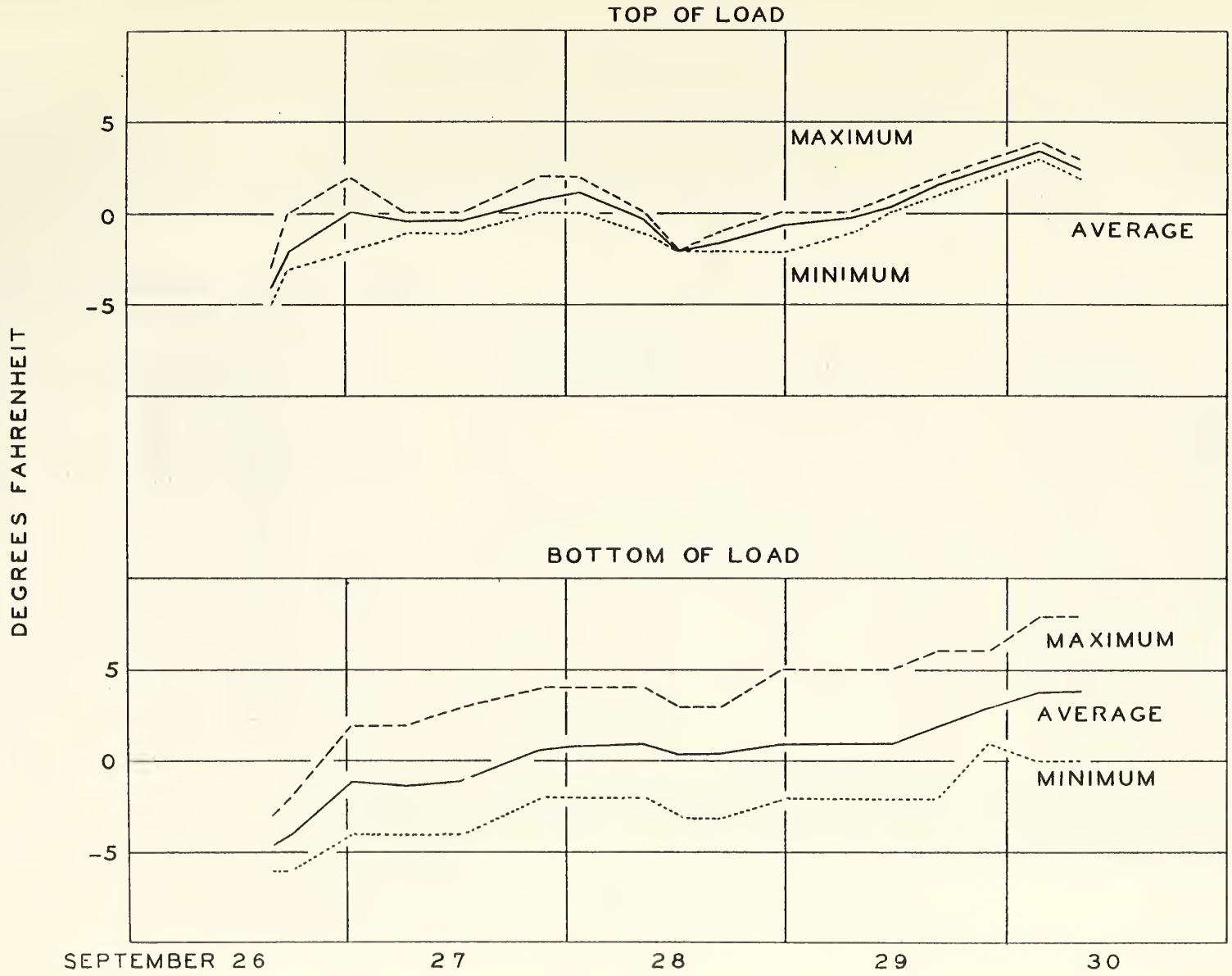

Figure 12.--Commodity temperatures at the top and bottom of the load in test No. III. (Plymouth, Fla., to Los Angeles, Calif.)

Table 6.--Temperatures recorded during transit test with truck-trailer, equipped with dry ice system of refrigeration, from Corona, Calif., to Orlando, Fla., October 6-10, 1952

Place	Date 1952	Time	Out-side temp.	Air temperature		Commodity temperature									Top commodity			Bottom commodity		
				TBCL 1/	BDRS	TBCL	THRS	THCL	TDCL	MHCL	BBRS	BBCL	BHRS	BDCL	Max.	Min.	Av.	Max.	Min.	Av.
			°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
Los Angeles, Calif.	10-6	9:15 a.m.	76			Initially iced before loading 1,005 pounds of dry ice														
Corona, Calif.	10-6	1:30 p.m.	82			Loading started														
Corona, Calif.	10-6	3:30 p.m.	82			Loading completed														
Corona, Calif.	10-6	3:50 p.m.	83	66	34	9	17	20	8	2	0	-3	-4	5	20	8	13.5	5	-4	-0.5
Desert Center, Calif.	10-6	7:45 p.m.	94	0	4	1	14	1	2	0	8	1	-1	0	14	1	4.5	8	-1	2.0
Phoenix, Ariz.	10-7	3:30 a.m.	68	3	3	-1	-2	-2	0	1	4	0	-2	-2	0	-2	-1.3	4	-2	0.0
Tuscon, Ariz.	10-7	8:20 a.m.	80	-5	4	-3	0	-2	0	0	3	0	0	0	0	-3	-1.3	3	0	0.8
State Line, Ariz.-N. Mex.	10-7	12:45 p.m.	78	0	0	0	0	-2	1	0	5	2	0	0	1	-2	-0.3	5	0	1.8
Las Cruces, N. Mex.	10-7	5:35 p.m.	72	0	3	0	0	0	2	0	5	-2	0	0	2	0	0.5	5	-2	0.8
El Paso, Tex.	10-8	12:30 a.m.	68	0	5	0	0	0	2	0	4	-2	0	0	2	0	0.5	4	-2	0.5
Toyah, Tex.	10-8	5:25 a.m.	58	0	7	0	0	0	3	0	4	-3	0	0	3	0	0.8	4	-3	0.3
Abilene, Tex.	10-8	1:00 p.m.	65	13	14	6	6	11	4	0	8	6	1	2	11	4	6.8	8	1	4.3
Abilene, Tex.	10-8	1:50 p.m.	66			Re-iced with 100 pounds of dry ice (no more available)														
Ft. Worth, Tex.	10-8	5:00 p.m.	66	12	15	9	8	13	8	0	10	7	3	3	13	8	9.5	10	3	5.8
Ft. Worth, Tex.	10-8	6:00 p.m.	65			Re-iced with 840 pounds of dry ice														
Dallas, Tex.	10-8	8:00 p.m.	68	-2	9	1	4	9	7	0	8	6	3	2	9	1	5.3	8	2	4.8
Shreveport, La.	10-9	1:15 a.m.	52	-8	4	-3	0	4	3	0	4	4	2	0	4	-3	1.0	4	0	2.5
Baton Rouge, La.	10-9	7:15 a.m.	54	-4	5	-2	0	4	6	0	4	3	1	0	6	-2	2.0	4	0	2.0
Mobile, Ala.	10-9	4:30 p.m.	63	-1	6	-2	0	4	9	0	3	3	0	0	9	-2	2.8	3	0	1.5
Quincy, Fla.	10-9	11:30 p.m.	54	-1	7	0	0	6	7	0	4	3	1	0	7	0	3.3	4	0	2.0
Orlando, Fla.	10-10	10:10 a.m.	58	5	10	3	1	8	5	0	6	5	2	1	8	1	4.3	6	1	3.5
Orlando, Fla.	10-10	10:30 a.m.	58			Estimated 400 pounds of dry ice remained														
Orlando, Fla.	10-10	11:00 a.m.	59			Unloading started														
Orlando, Fla.	10-10	12:30 p.m.	60			Unloading completed														

1/ For explanation of thermometer locations, see page 6.

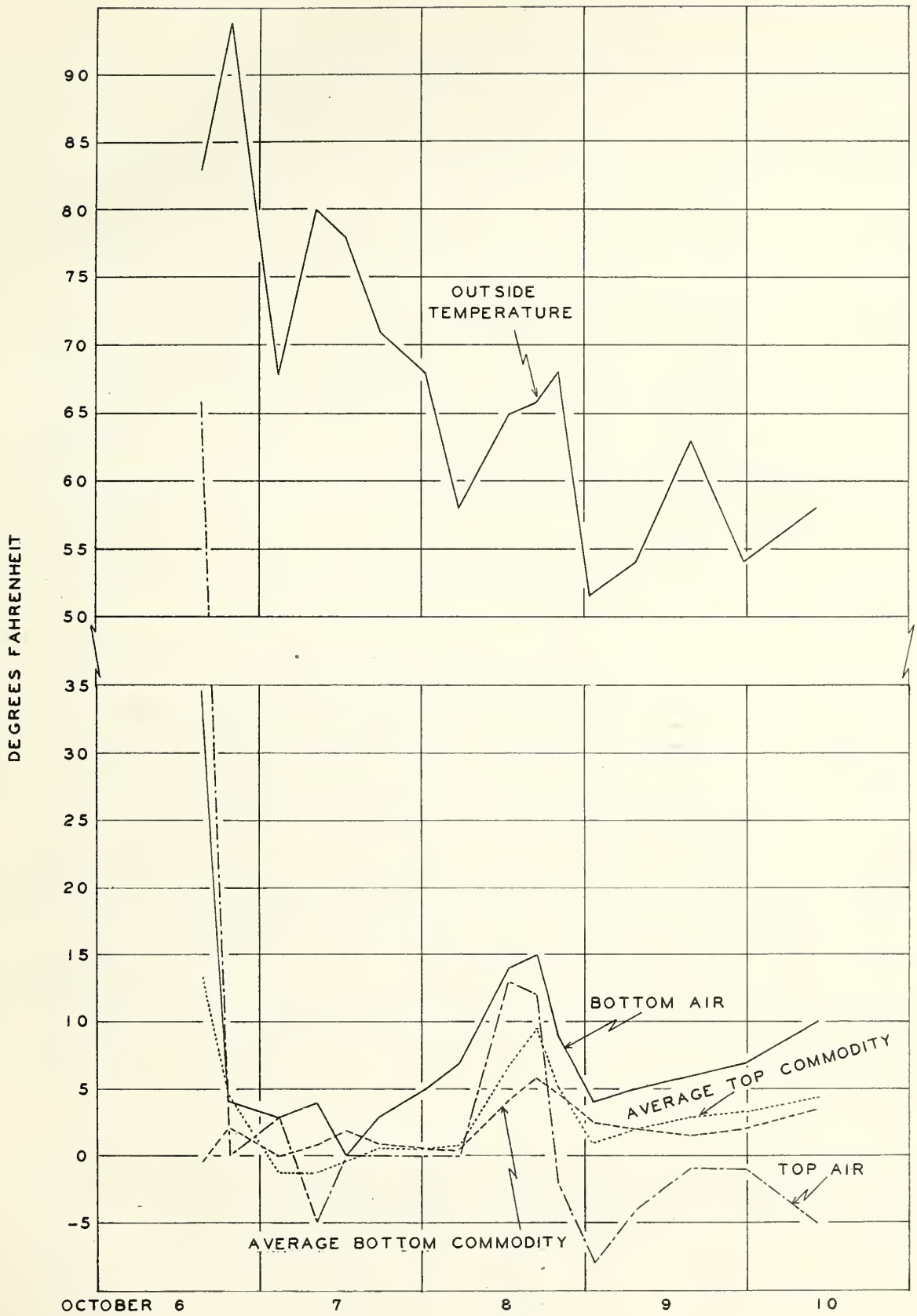

Figure 13.--Air and commodity temperatures during transit test No. IV. (Corona, Calif., to Orlando, Fla.)

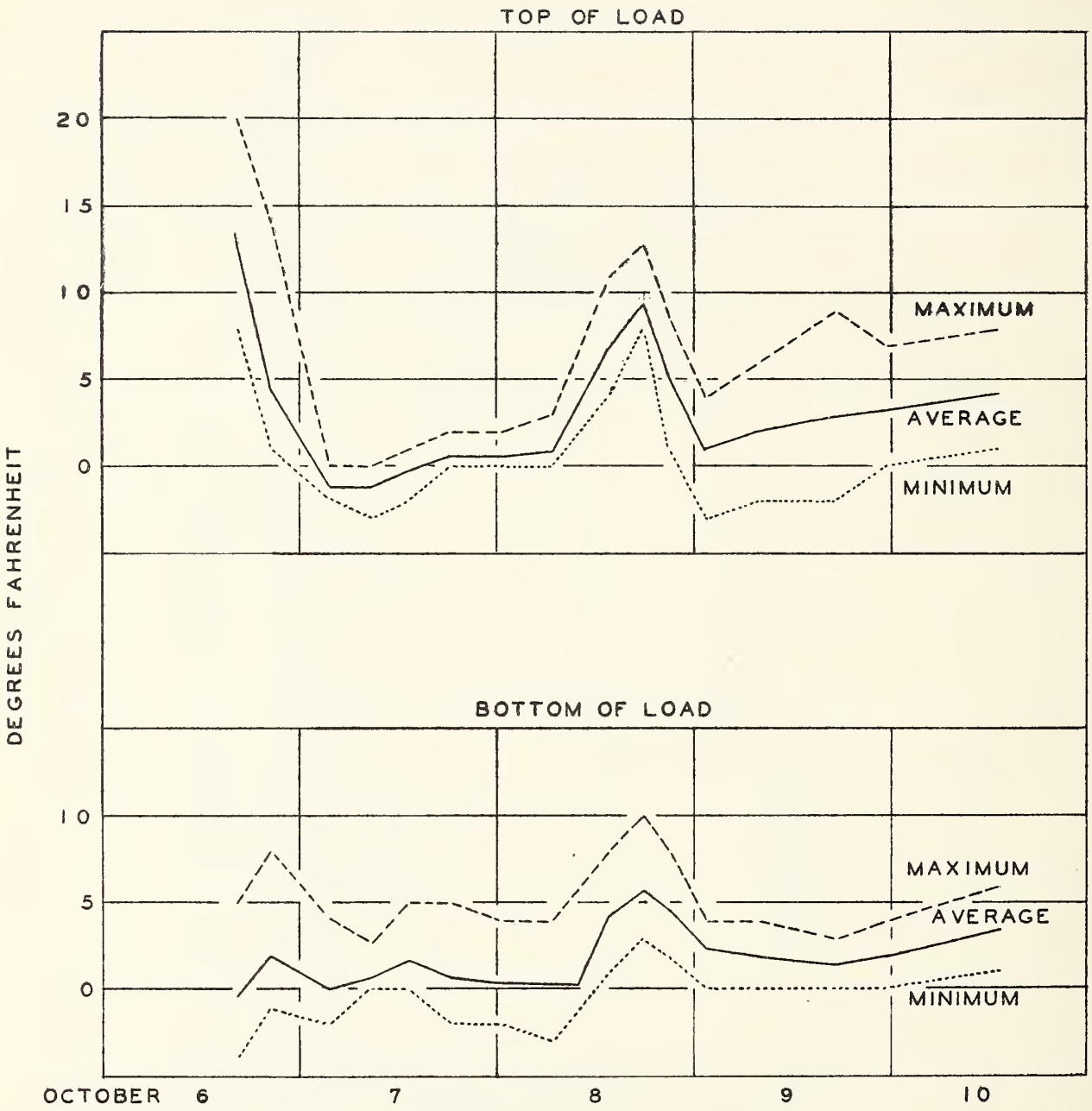

Figure 14.--Commodity temperatures at the top and bottom of the load in test No. IV. (Corona, Calif., to Orlando, Fla.)

Table 7.--Consumption rate per hour, total consumption, and cost of dry ice for refrigeration to hold frozen citrus concentrate during four transit tests, 1952

Dry ice for refrigeration	Auburndale, Fla. to San Antonio, Tex.		Plymouth, Fla. to Perth Amboy, N.J.		Plymouth, Fla. to Los Angeles, Calif.		Corona, Calif. to Orlando, Fla.	
	Weight	Cost	Weight	Cost	Weight	Cost	Weight	Cost
	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Initial icing	810	25.11	908	28.15	825	25.58	1,005	31.16
Supplied en route	710	22.01	450	13.95	1,500	46.50	940	29.14
Total supplied	1,520	47.12	1,358	42.10	2,325	72.08	1,945	60.30
Remained at end of test	320	9.92	150	4.65	500	15.50	400	12.40
Total consumption	1,200	37.20	1,208	37.45	1,825	56.58	1,545	47.90
Consumption rate per hour	26	.81	24	.74	20	.62	1/ 17	.53

1/ See text for explanation of this relatively low rate.